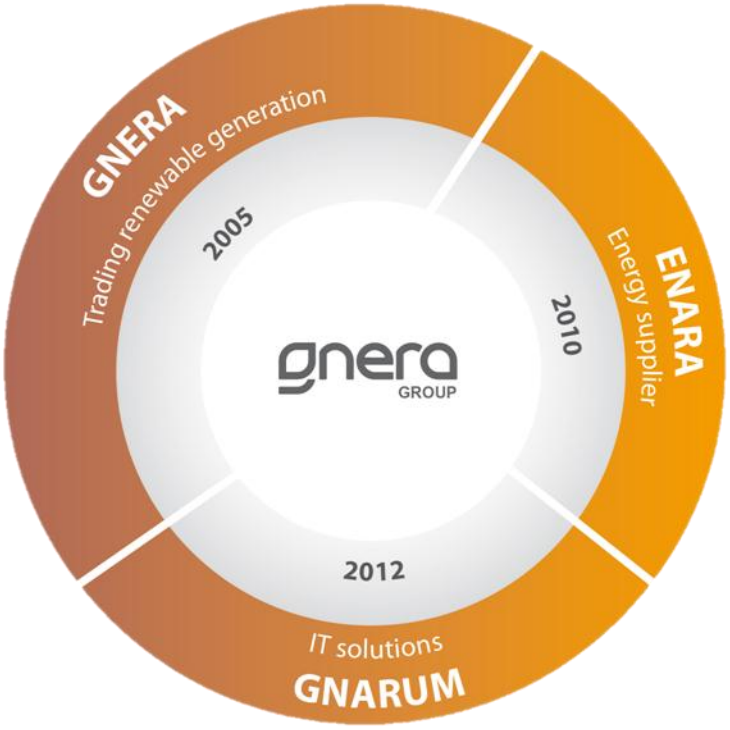
Gnarum

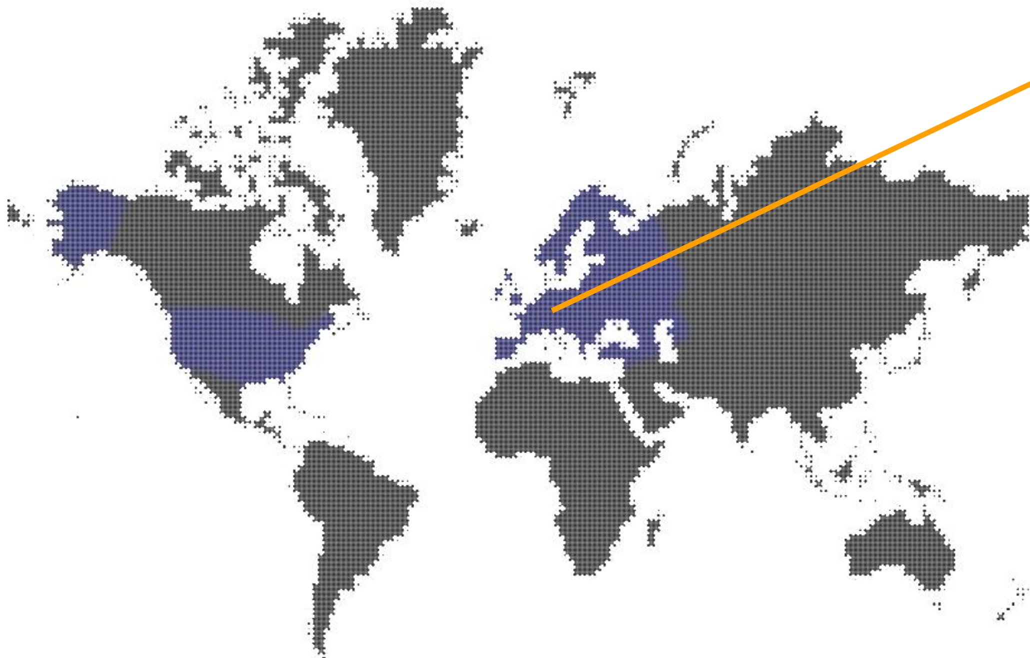
Energy forecasting as a way to integrate renewable energies

Content

- ***Gnarum = I knew it!***
- IT solutions for renewables
- Added-value knowledge of the energy market world wide.



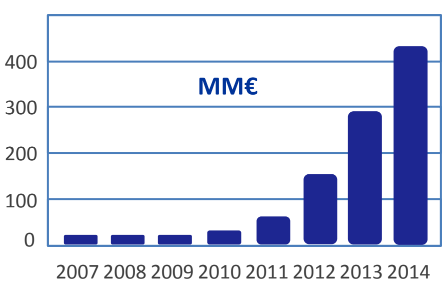
WHO WE ARE. International Presence



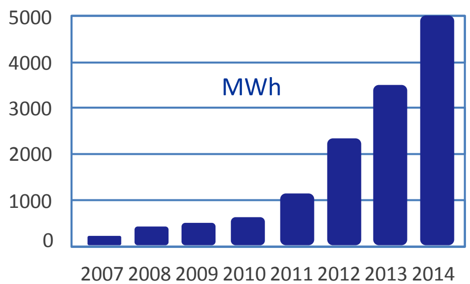
- All renewable technologies
- More than 400 Plants
- 24x7x365 Monitoring Center

Equivalent to 1,000,000 households demand

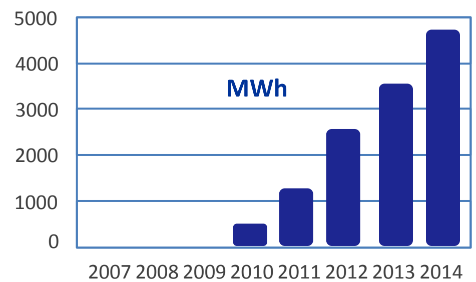
Sales Volume



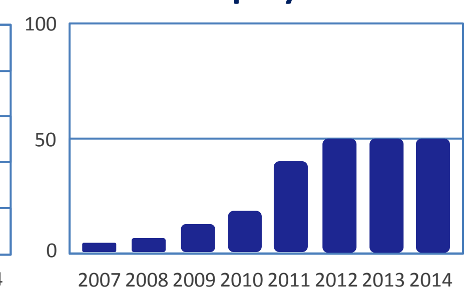
Traded Energy



Forecasted Energy



Employees



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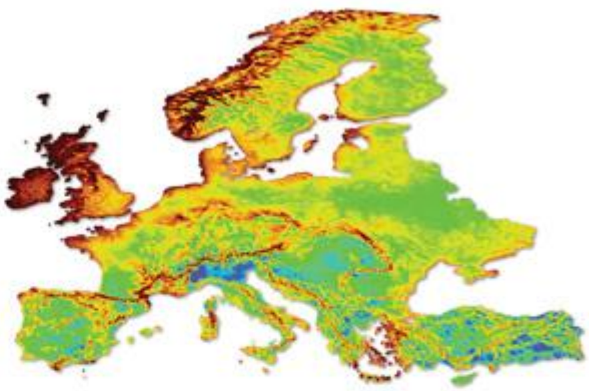
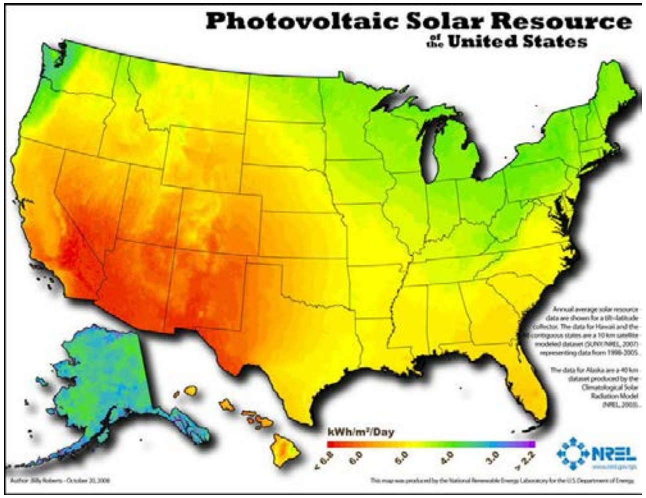
Energy Forecasting

Resource Assessment:

- Statistical analysis based on past metering.
- Monthly, yearly averaged values
- Design of power plant
- Focus on profitability of power plant.
  - Annual budget planning
  - PPA negotiation

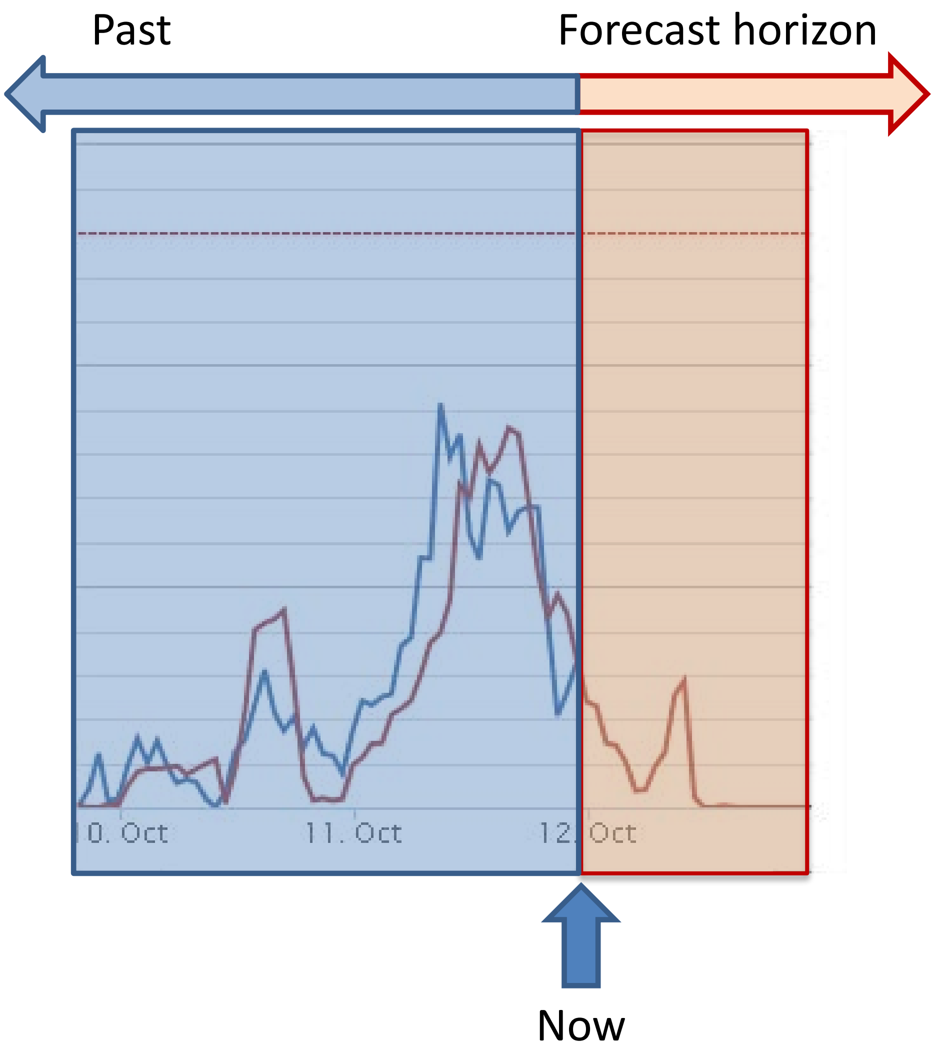


Wind Resource



Grid Forecasting (Short-term forecasting):

- Future estimates of energy production.
- Energy values every 15-min, hour or market timebasis.
- Power plant on operation
- To enhance the management of intermittent energy sources
  - Operation into energy market
  - Maximize benefits



Grid forecasting and resource assessment are different:

- Different methodologies
- Different objectives
- Different applications
- Diffferent time scales
- Different spatial scales
- Different accuracy

Why forecasts are important?

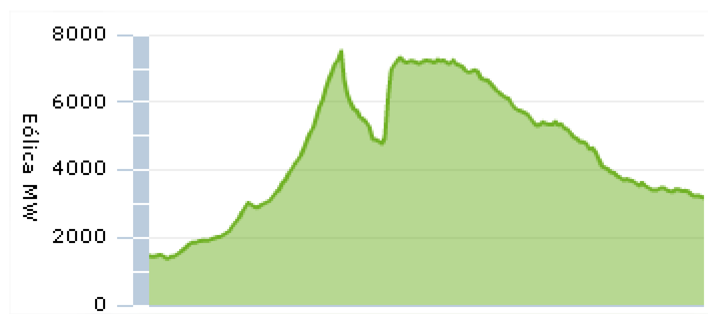
Renewable Energy Sources

- Intermittent vs non-intermittent
- Dispatchable vs non-dispatchable

Integration barriers for renewable energies:

- Electric systems
  - Frequency: 50 Hz (Europe) – 60 Hz (US)
  - Voltage balance according to operational limits
- Regulation
- Other reasons
  - Economic, territory, etc.

Specially important in weak grids



One day wind production

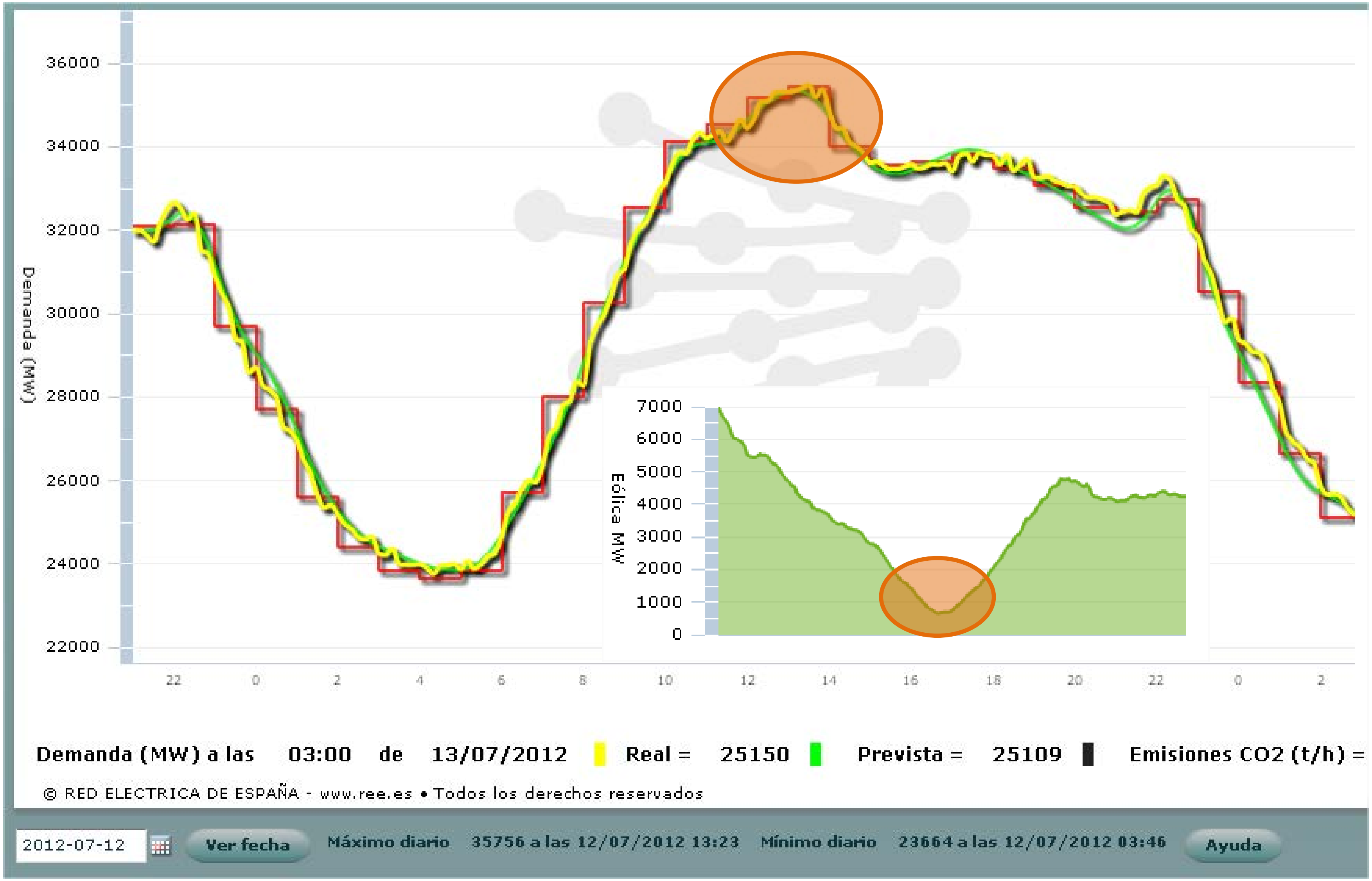
TSO must balance generation and consumption

- Stability of grid parameters: frequency, power, etc.
- Unbalance may lead whether to disconnection or to extra generation costs.

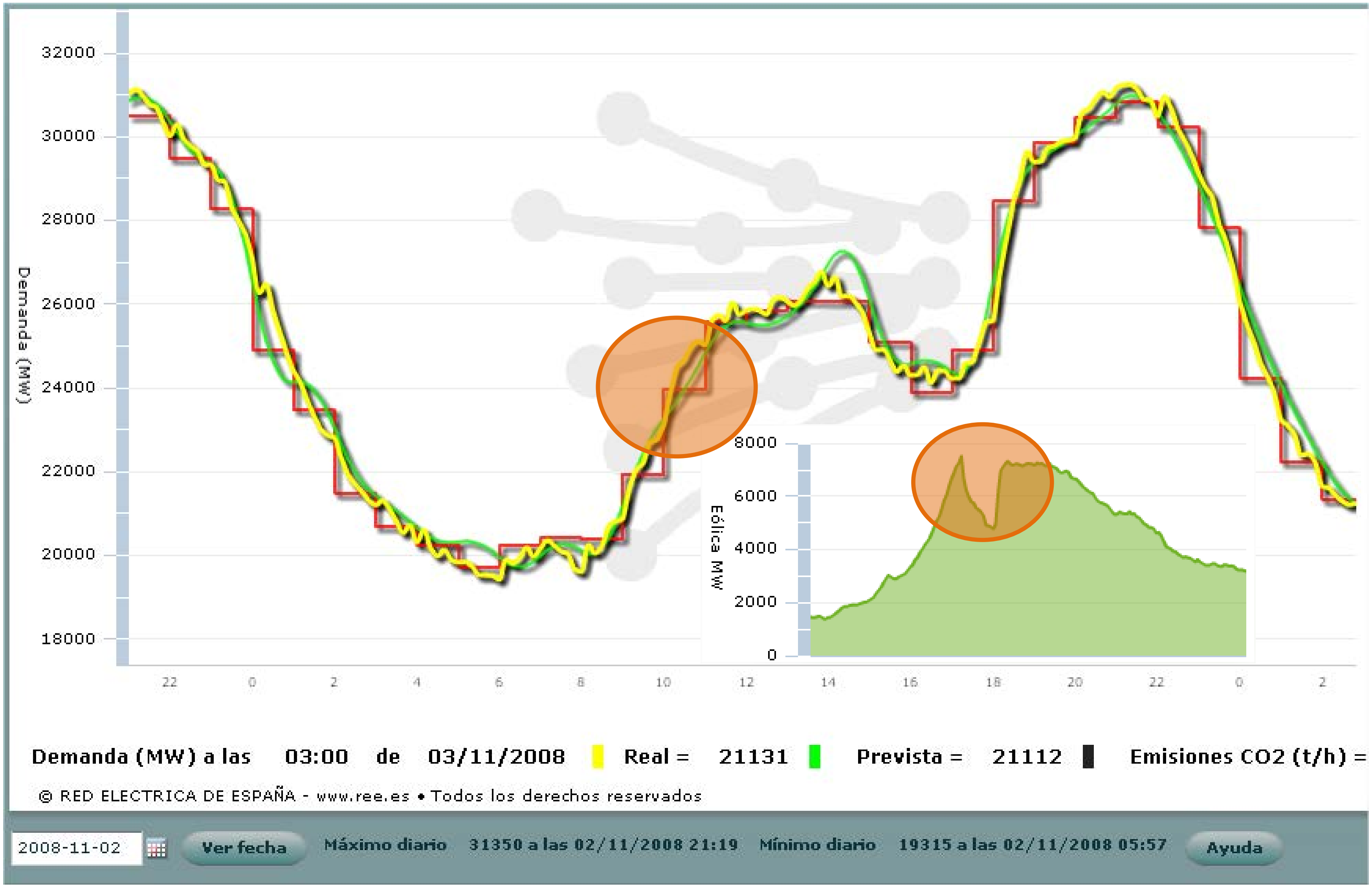
Forecasts are useful for:

- Scheduling the energy exported by different generation technologies to the grid.
- Maximizing the value of energy produced by intermittent sources (wind, solar, hydro,…)

WHY FORECASTS ARE IMPORTANT?

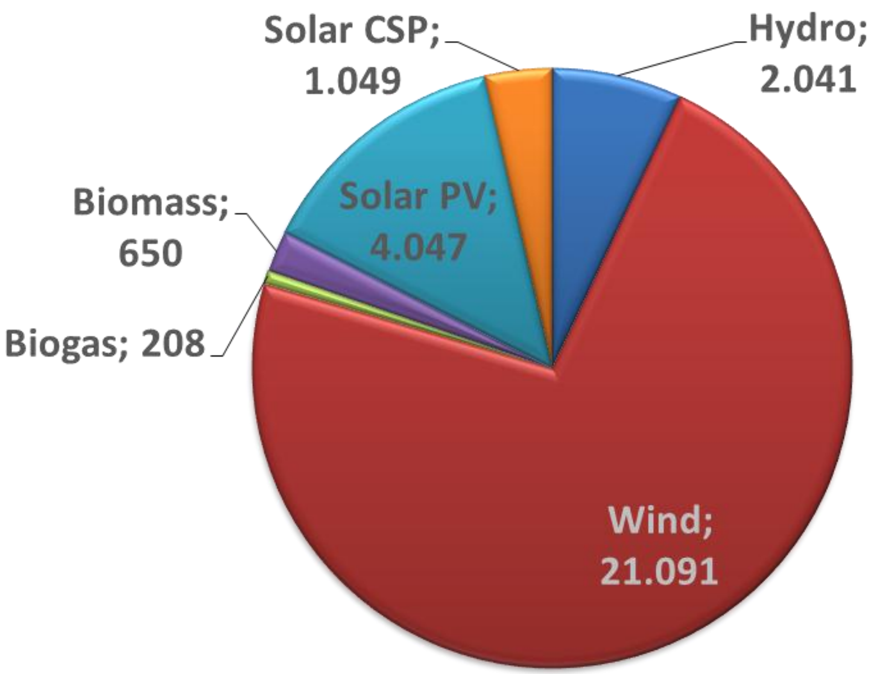


WHY FORECASTS ARE IMPORTANT?

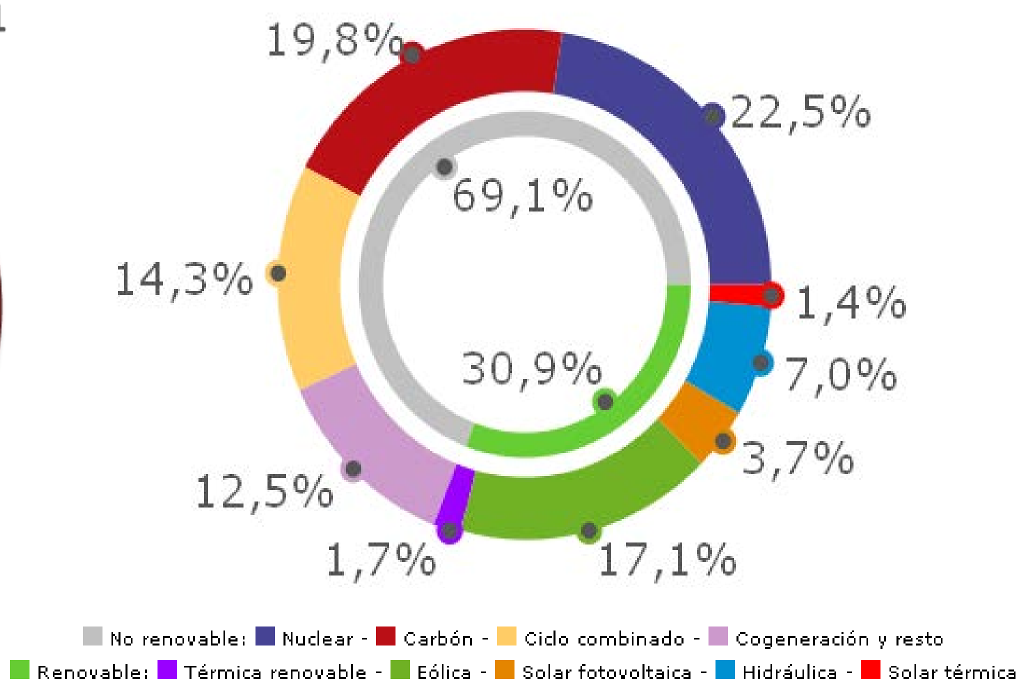


Renewable Energy Integration in Advanced Markets

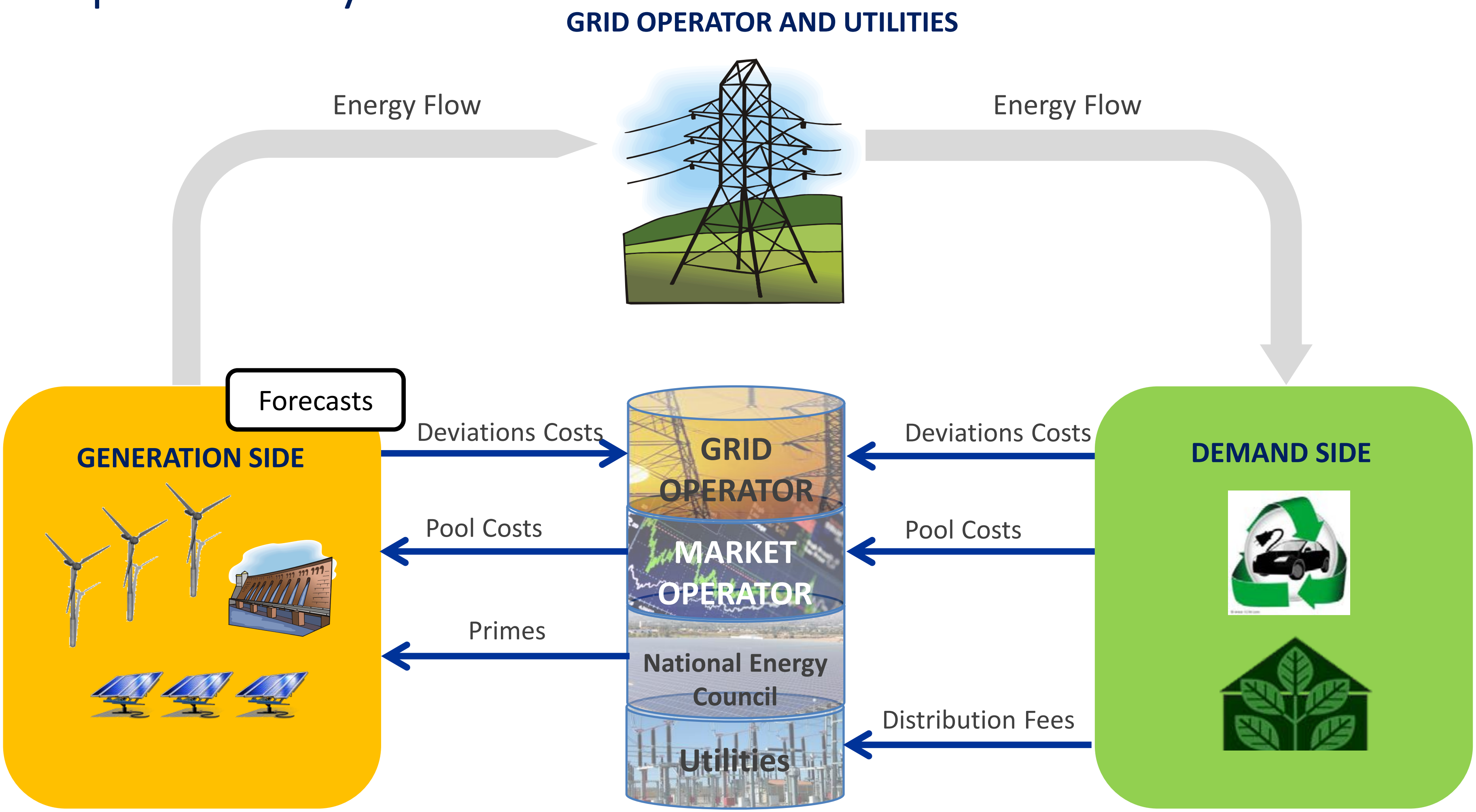
Installed RE capacity Dec- 2011 (MW)



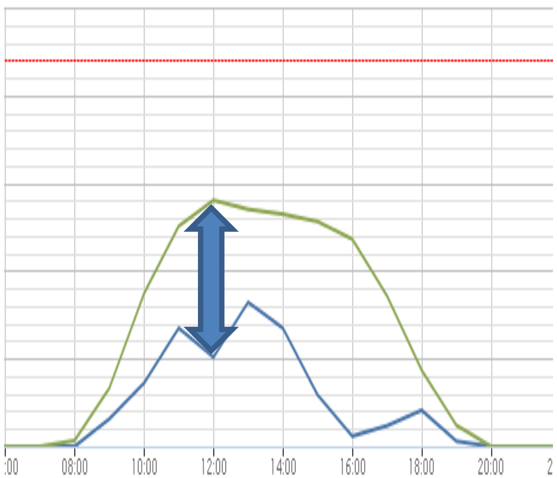
Generation mix 2012

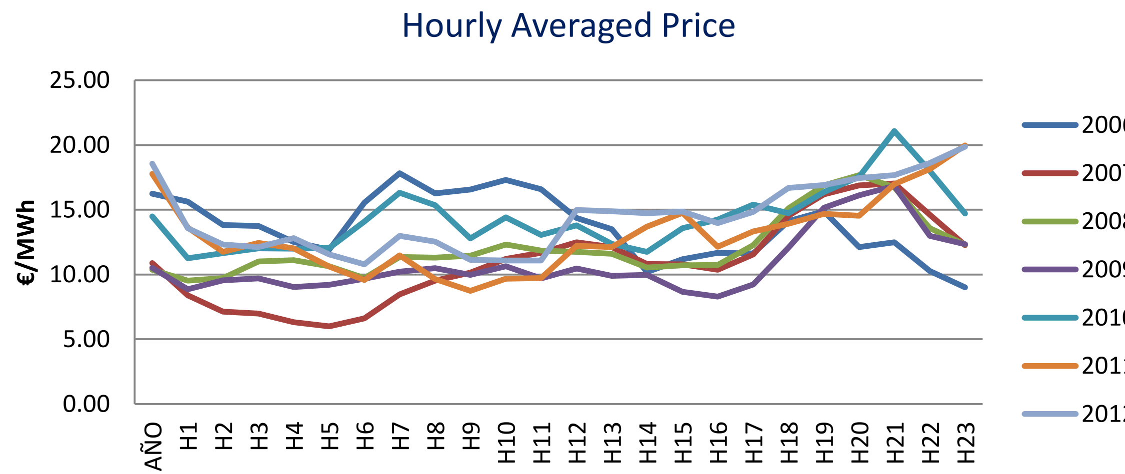


Spanish FIT System



Imbalancing penalties





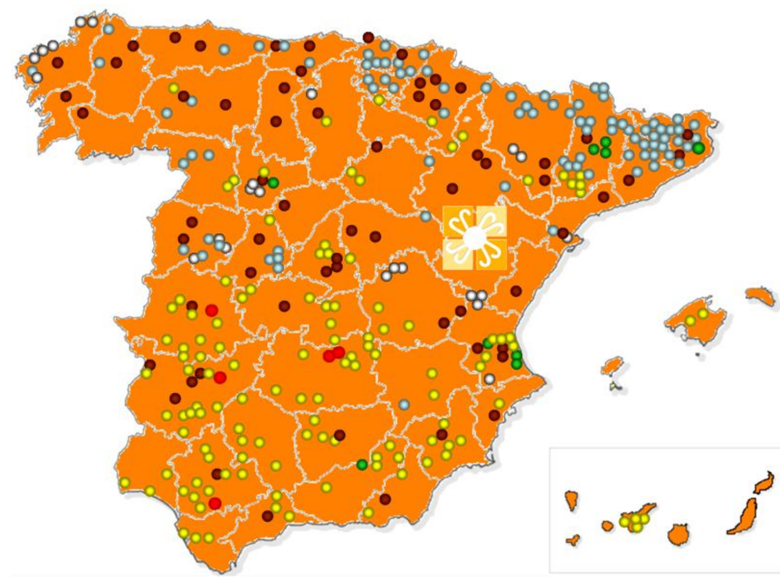
Costs = P x D

P = Imbalancing price
D = Deviation

Average cost 15 €/MWh

Imbalancing Penalties are directly proportional to unaccuracy or deviation gnera energía y tecnología s.L.

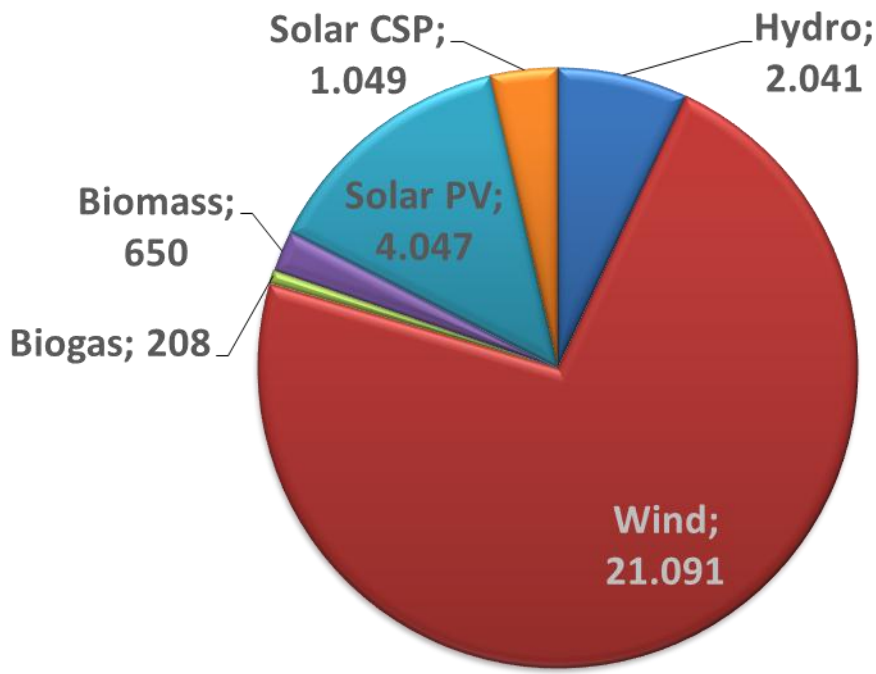
gwise



April to September 2012:

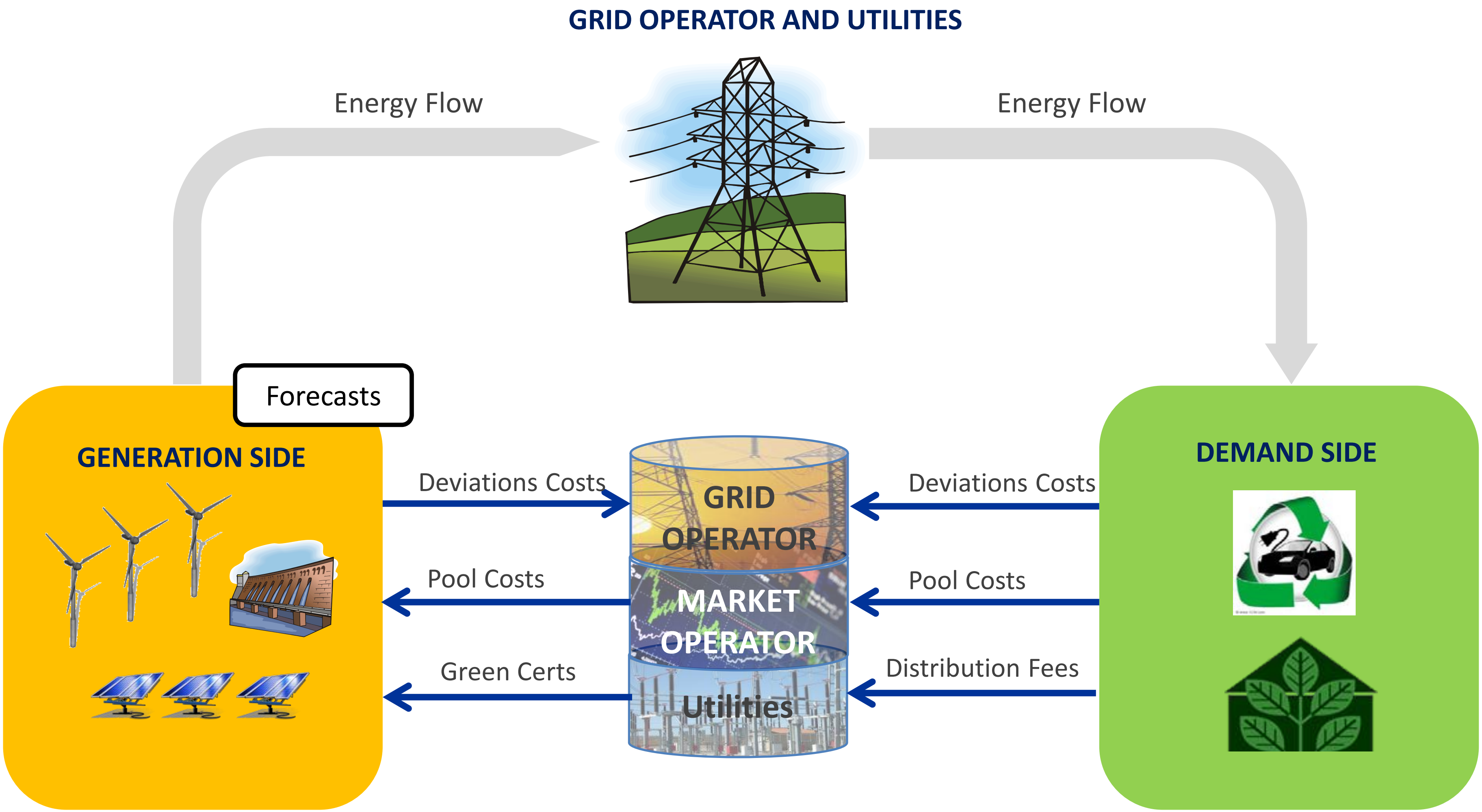
	Nameplate Capacity	Costs w/o Forecasting	Costs Forecasting	Savings
Wind	140 MW	0.86 M€	0.26 M€	0.6 M€
PV	513 MW	4.05 M€	0.48 M€	3.57 M€
Hydro	125 MW	0.6 M€	0.05 M€	0.55 M€
TOTAL	**778 MW**	**5.51 M€**	**0.79 M€**	**4.72 M€**

BUSINESS CASE. Spanish RE production.

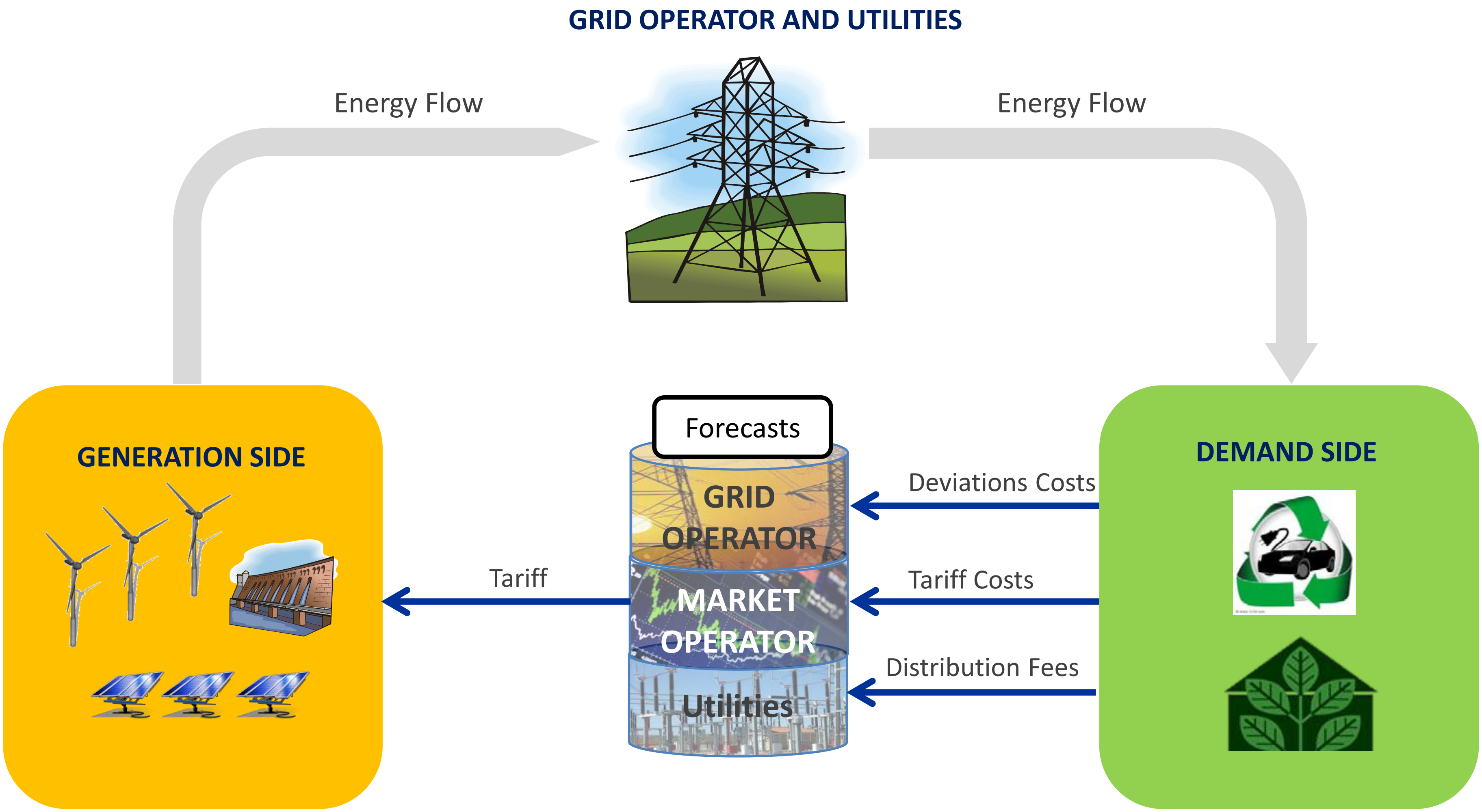


	Nameplate Capacity	Costs w/o Forecasting	Costs Forecasting	Savings
Wind	21,091 MW	295 M€	118 M€	177 M€
PV	4,047 MW	40.79 M€	4.8 M€	35.99 M€
Hydro	2,041 MW	17.14 M€	1.54 M€	15.6 M€
TOTAL	**27,179 MW**	**352.93 M€**	**124.34 M€**	**228.59 M€**

General FIT System (market option)



Europe FIT System (feed-in tariff option)



Other markets in Europe

Country	Wind Inst (MW)	PV Inst (MW)	Balancing Costs	Green Certs	Feed in tariff	Forecasts
Germany	29,075	26,000	Y	N	Y	Y
Italy	6,747	13,400	Y (2013)	Y	N	Y
Romania	1,200	262	Y	Y	N	Y
Poland	1,611	3,5	Y	Y	N	Y
Bulgaria	612	133	N	N	Y	Y
US	49,802	3,819.14	Y	Y	N	Y

Either at GO side or Generation side, forecasts are always needed!!

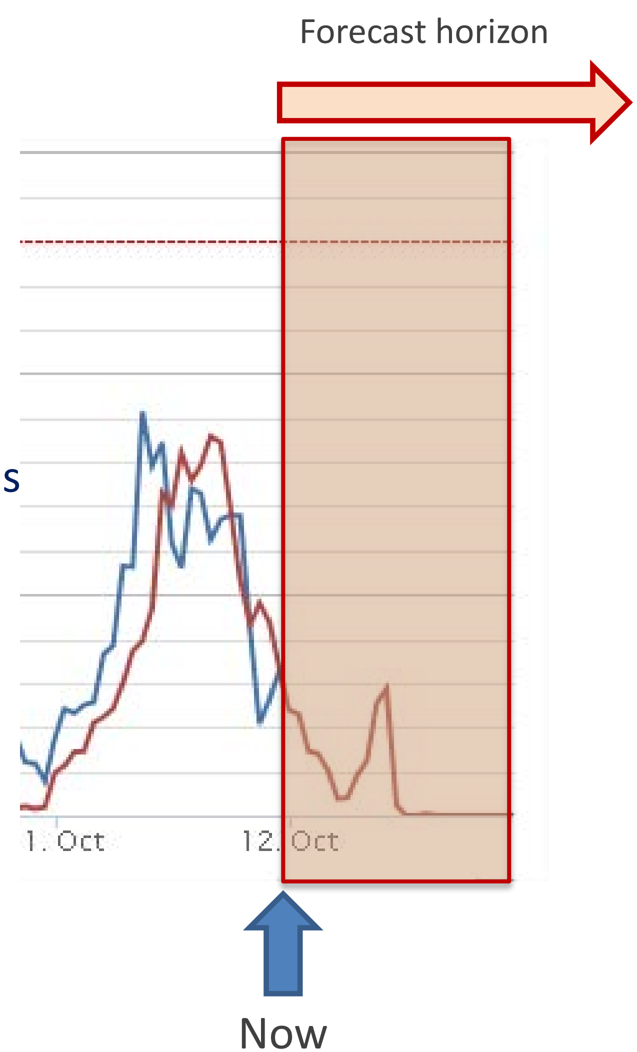
Forecasting Systems
State of the Art

"Prediction is very difficult, specially if it is about the future"

(Niels Bohr, Nobel laureate in Physics)

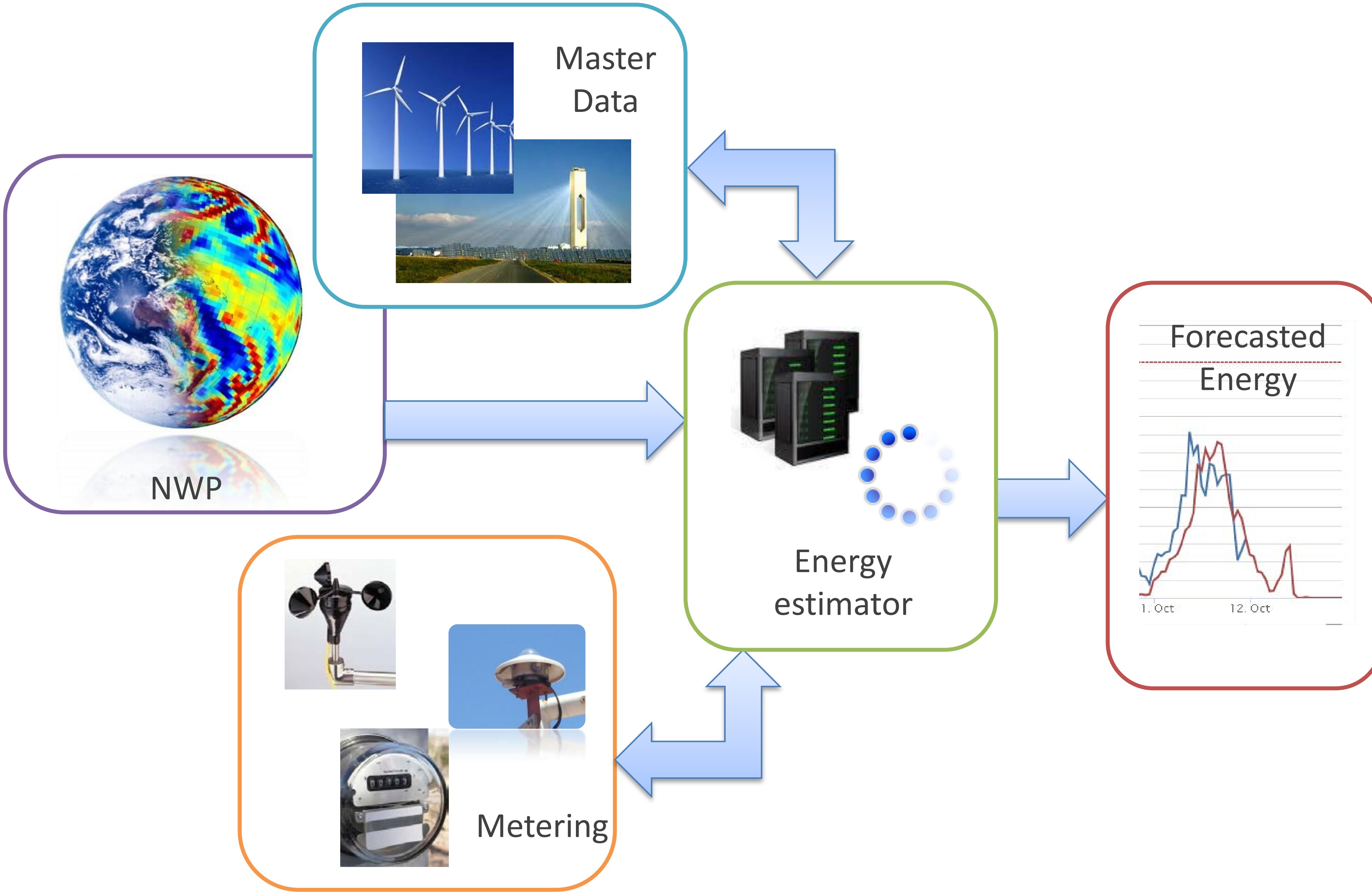
Forecasting Horizon Time Scales:

- **Nowcasting**
  - Seconds to minutes ahead
  - Grid security
- **Short-term Prediction**
  - Up to 96-120 hours ahead
  - Scheduling or electricity market operations
- **Medium-Large Prediction**
  - Several days ahead up to 2 weeks
  - Schedule maintenance stops.



Forecasting Spatial Coverage:

- - **Worldwide**


Master
Data
NWP
Energy
estimator
Forecasted
Energy
1. Oct
12. Oct
Metering

Main power plant characteristics are usually required

- Geographical localization
  - Latitude, Longitude
  - UTM coordinates

- Power plant characteristics
  - wind, solar, hydro,…
  - number of windmills, solar pannels
  - nameplate power
  - specific technical configuration

- Digital Terrain Model

- Other issues or special characteristics

Master Data

Numerical Weather Prediction Models (NWP)

Mathematical models of the atmosphere and oceans used to predict the weather based on measured initial conditions.

NWP

Global Models

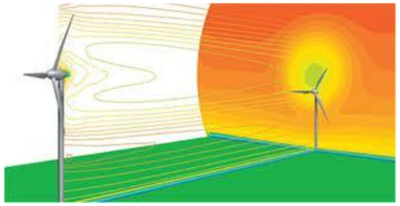
- Earth globe atmosphere state.
- 0,5º latitude spatial resolution
- 3 hours time resolution (one value every 3 forecasted hours)

Regional Models

- Downscaling from global model
- Maximum resolution of 1-2 Km
- Minutes time resolution

Microscale Models

- Downscaling
- Some meters spatial resolution
- Seconds time resolution



Numerical Weather Prediction Models (NWP)

Solve a complex system of partial derivative equations that describe the physic laws that determine the state of the atmosphere across space and time.

Initialization (Analysis)

- - Measures of main atmospheric parameters by satellites, weather stations,..

Computations Involved

- Discretized Navier-Stokes Equations, Fluid mechanics,…
- Numerical methods to solve these equations on a grid
- Supercomputing infrastructure is required to solve these problems.

Physical Parametrization

- Atmospheric phenomena are modeled through parameterizations.
- Atmospheric modellers (forecasters) provide different values for these parameters that better suit for atmospheric states.

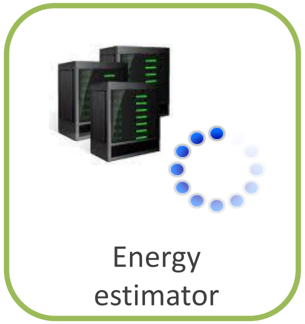
Metering strategies

- No-metering option
- Off-line metering (periodic updates)
- On-line metering (daily updates)
- Real Time metering

Metering

Main measures of interest

- Weather variables: wind, pressure, radiation, temperature, hummidity
- Output Power



Output energy estimation

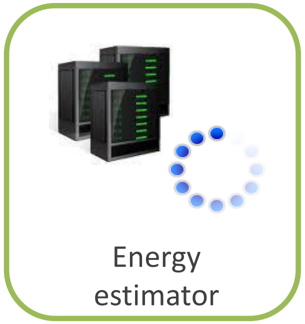
- Many approaches have been developped in the literature
- Different target objectives lead to different strategies
- Data availability is an important design criterion

Approaches

- Theoretical (physical) approaches
- Statistical approaches
- Combined

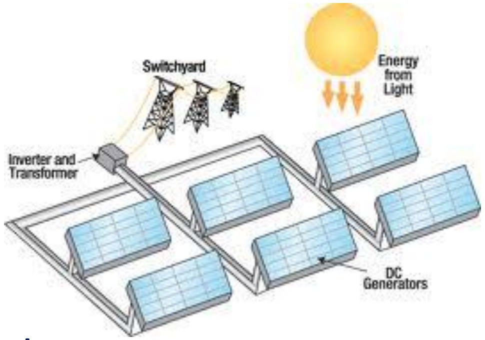
Theoretical (Physical) Approaches

Output energy is obtained as an analytical function of a set of input parameters.



Solar power plants

- Equations to compute in-plane module radiation.
- Model to compute DC power and output energy.



Wind power plants

- Turbine power curve to estimate output power
- Wind farm energy is the sum of every turbine minus wake effects, theoretically modelled.

Advantages

- No historical data needed to predict
- Easy to implement

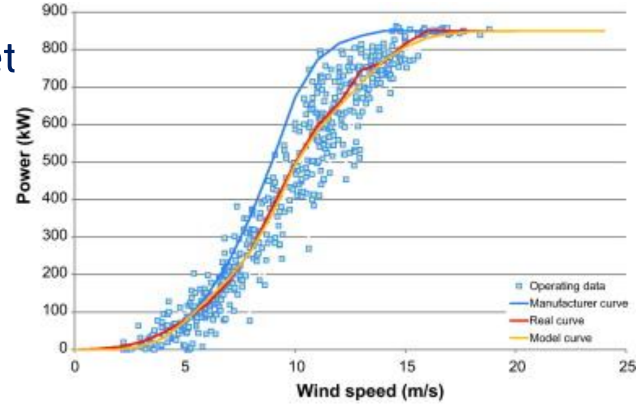
Disadvantages

- Very sensitive to parameter misconfiguration.

Statistical Approaches

Output energy is obtained through an statistical analysis of historical data.

- Power plant power curve is statistically modeled
- Different technologies might be applied:
  - ANN, regression methods, curve fitting, AI, et
  - Ensembles
- Output energy is suited to minimize an objective
  - Portfolio vs single power plant deviation
  - MAE, RMSE, etc.



Advantages

- More robust architectures
- Continuously adapted to data
- More accurate

Disadvantages

- More difficult to implement
- Depend on data availability
- High performance computation resources needed

Combined Approaches

Output energy is obtained through a combination of theoretical calculations and statistical analysis.

- Statistical Approaches work together with theoretical models.

Advantages

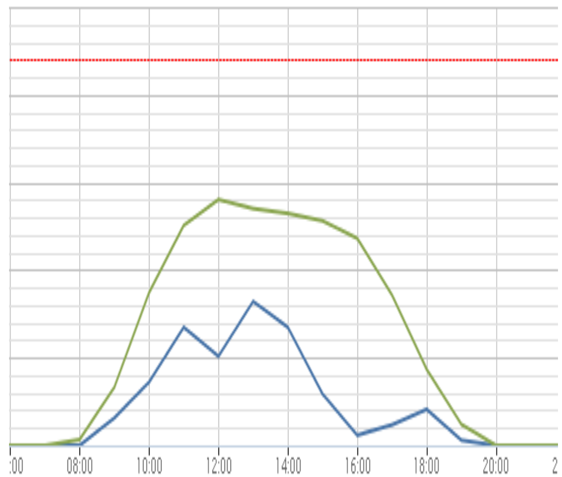
- Combines advantages of previous methods

Disadvantages

- More difficult to implement
- High performance computation resources needed

Error sources

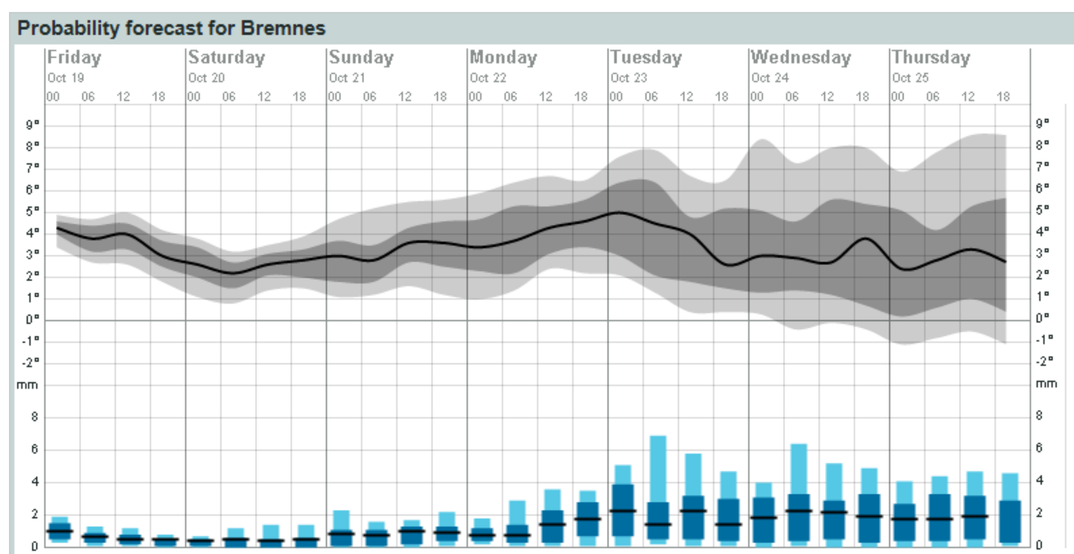
Main error comes from NWP models

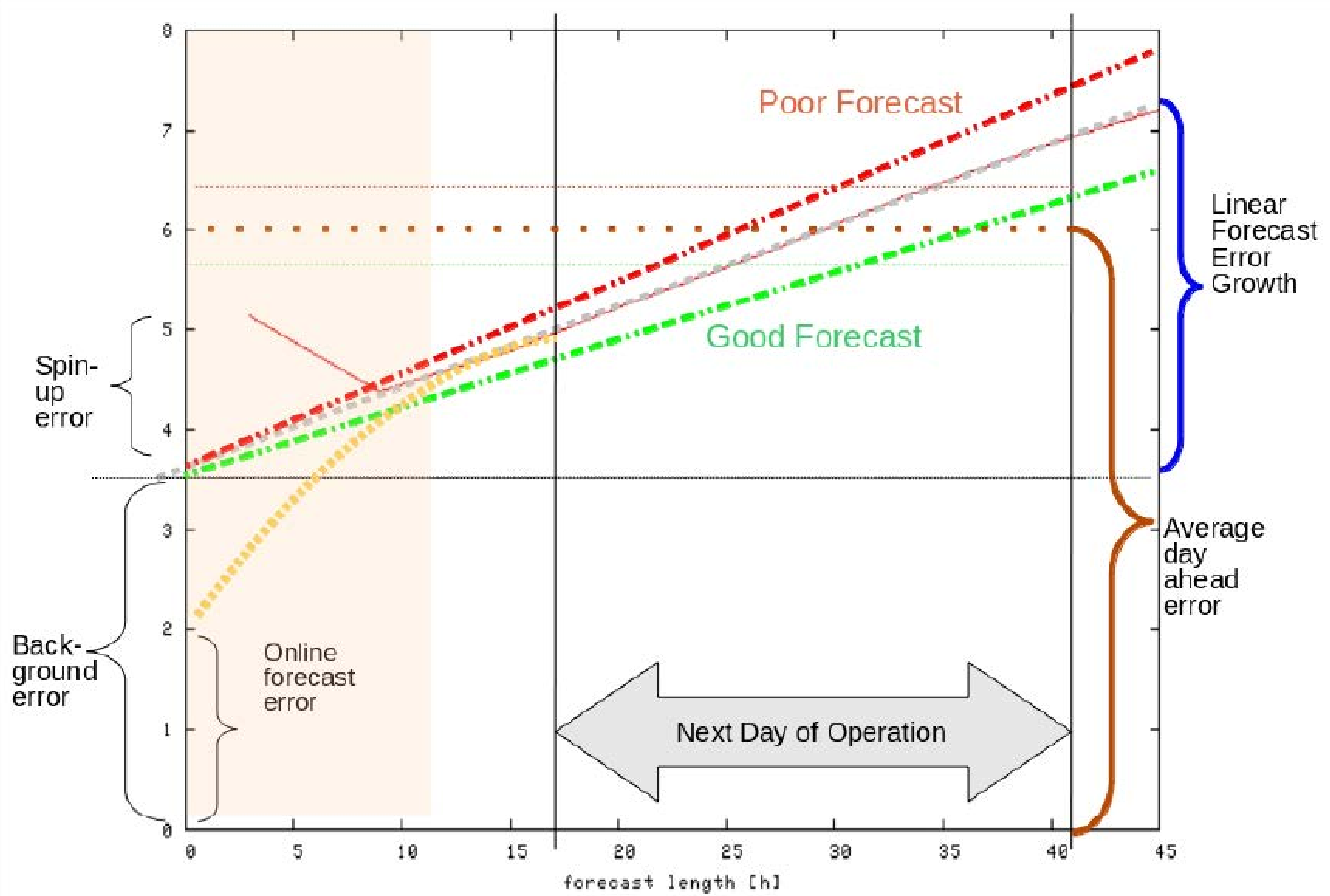


Level errors

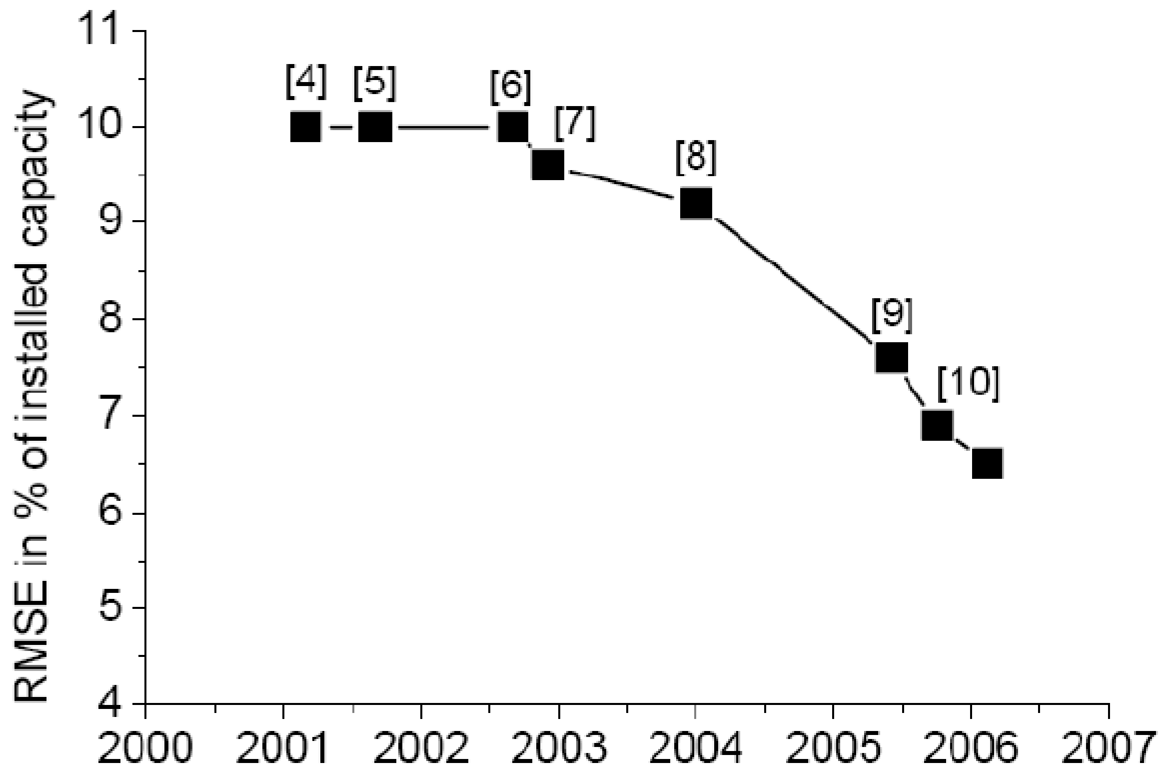
Phase errors

Uncertainty estimation





Source: Möhrlen, C. 3rd Workshop on Best Practice in the Use of short-term prediction of Wind Power. 2009.



RMSE in % of installed capacity
11
10
9
8
7
6
5
4
2000
2001
2002
2003
2004
2005
2006
2007
[4]
[5]
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Conclusions

- Forecasting helps TSO to manage grid operation
- Advanced energy markets integrate forecasts to maximize the benefits of RE sources.
- NWP models require high computing performance
- Forecasting systems have improved their performance in the last years.
- Forecast services can be offered worldwide!

Thank You!

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